Report Documentation Page

Report Documentation Page	*Form Approved* *OMB No. 0704-0188*

Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.

1. REPORT DATE **JUN 2010**	2. REPORT TYPE	3. DATES COVERED **00-00-2010 to 00-00-2010**
4. TITLE AND SUBTITLE **Phase-Locked Second Harmonic Generation in GaAs nanocavities**		5a. CONTRACT NUMBER
		5b. GRANT NUMBER
		5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER
		5e. TASK NUMBER
		5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **AEgis Technologies Group,410 Jan Davis Dr,Huntsville,AL,35806**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S)
		11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES
See also ADA541135. Presented at the Advanced Photonics and Renewable Energy: 2010 OSA Optics and Photonics Congress Held in Karlsruhe, Germany on June 21-24, 2010. Sponsored by EOARD.

14. ABSTRACT
We theoretically study light propagation through sub-wavelength apertures on a silver substrate filled with GaAs, in the enhanced transmission regime. We predict enhanced conversion efficiencies even under high absorption conditions.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**2**	

Phase-Locked Second Harmonic Generation in GaAs nanocavities

M. A. Vincenti, D. de Ceglia, M. C. Buncick
AEgis Technologies Group, 410 Jan Davis Dr., Huntsville, AL 35806
mvincenti@aegistg.com

M. Scalora, M.J. Bloemer
Charles M. Bowden Research Center AMSRD-AMR-WS-ST, RDECOM, Redstone Arsenal, Alabama 35898-5000, USA

Abstract. We theoretically study light propagation through sub-wavelength apertures on a silver substrate filled with GaAs, in the enhanced transmission regime. We predict enhanced conversion efficiencies even under high absorption conditions.

OCIS codes: (240.6680) Surface Plasmon, (120.7000) Transmission, (240.3695) Linear and nonlinear light scattering from surfaces, (310.6628) Subwavelength Structures, nanostructures.

1. Introduction

During the last few decades several groups have pointed out the existence of a double peak structure in the second harmonic generation (SHG) process under phase and group velocity mismatch conditions. This trapping process has been demonstrated to be produced by the inhomogeneous term solution of the wave equation at the interface between a linear and a nonlinear medium [1-4]. The evidence for this phenomenon can be found in several experimental works, where the large phase mismatch between the fundamental and the second harmonic waves allows the observation of two distinct SH pulses travelling at different phase and group velocities [5-7]. As recently shown, this peculiar behavior can also be interpreted as a phase-locking mechanism that remains valid also for negative index [8] or absorbing materials [9, 10] thanks to a trapping and dragging mechanism between the fundamental and phase-locked generated pulse [6-10]. It has also been demonstrated that sub-wavelength apertures carved on metal substrates lead to an enhanced linear response [11], and that surface waves and cavity effects are simultaneously important also in nonlinear processes [12]. In this paper we combine the resonant behavior of these structures with the phase locking mechanism to study nonlinear wave propagation including second and third harmonic generation in wavelength shorter than the band edge, where the nonlinear optical coefficients may be unusually high (i.e. GaAs and or GaP in the visible and UV regimes).

2. Linear response of a single sub-wavelength slit on Silver substrate and the enhanced nonlinear response

For simplicity we consider a silver [13] layer having thickness *w* and a single aperture of size *a*, which has been filled with GaAs. A necessary and sufficient condition for phase locked harmonic generation to occur in the absorption region is that the pump itself be tuned to a region of transparency. By tuning the pump at $\lambda = 1064$nm we have $\varepsilon(1064)_{GaAs} \sim 12.10 + i0$. Both second (532nm) and third (354nm) harmonic wavelengths are tuned deep in the absorbing regions and no harmonic generation is expected. Nevertheless, as already shown in the case of planar Fabry-Perot cavities, our calculations show the generation of SH and TH fields phase locked to the pump [10] that resonate inside the nano-cavity. In order to maximize the linear response at $\lambda = 1064$nm we varied the thickness of the substrate and aperture size and obtained a transmission map that clearly reveals the strong resonant nature of the structure (see Fig.1). We thus sought to enhance the nonlinear response that we previously reported on similarly resonant but empty sub-wavelength structures [12]. We simulated a single 60nm-lit carved on a silver substrate of variable depth filled with GaAs. We performed our simulations by assuming a $d_{14} = d_{25} = d_{36} = 50$ pm/V [14], an incident TM-polarized incident pump signal having peak intensity $I_0 = 2$ GW/cm^2. The mere assumption that the metal is nonlinear via Coulomb and Lorentz contributions [12] makes it possible to generate both TE- and TM-polarized harmonic fields, as Fig.2 demonstrates. These fields are generated even under high-absorption conditions, and survive thanks to a phase locking mechanism that sets in between the pump and its harmonics.

NME19.pdf

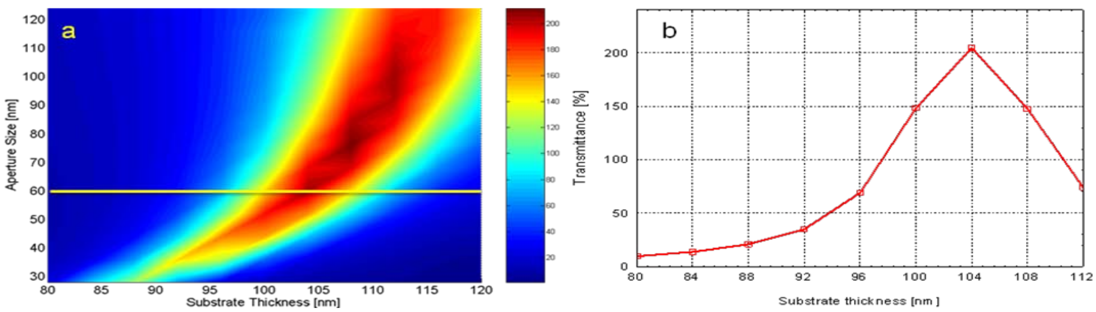

Fig.1. (a) Transmission map @ λ=1064nm for a single slit carved on a silver substrate, filled with a material having ε_X=12.10+ i0. The maximum for the transmission is obtained for a 76nm aperture carved on a 104 nm substrate (T = 212 %). (b) Transmittance vs. Substrate thickness for a slit 60nm wide, and correpsonds to tracing the yellow line in Fig.1a.

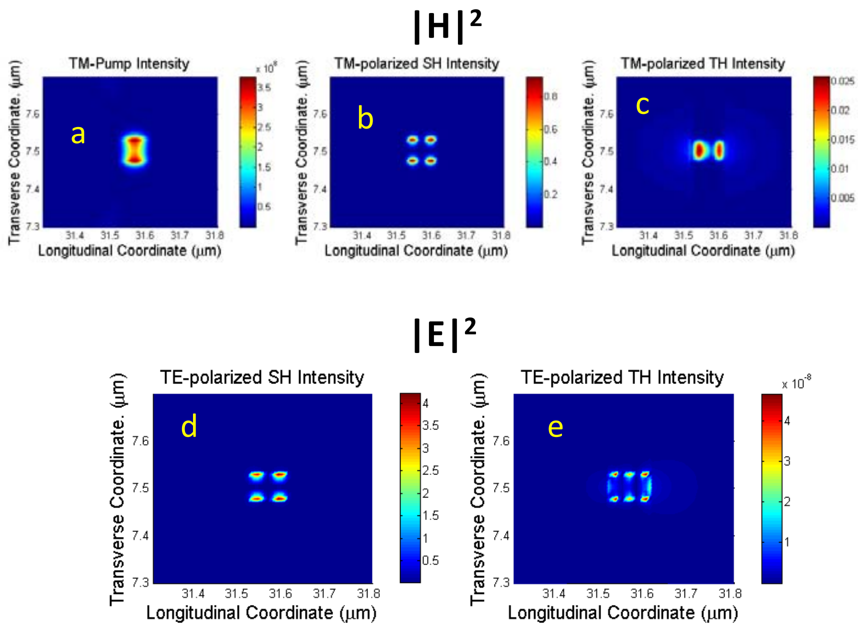

Fig.2: TM-polarized incident pump (a), SH (b) and TH (c) Magnetic intensity profiles; TE-polarized SH (d) and TH (e) electric field intensities inside the 60nm wide by 104nm long nano-cavity.

5. References

[1] J. A. Armstrong et al., Phys. Rev. **127**, 1918 (1962).

[2] N. Bloembergen, and P. S. Pershan, Phys. Rev. **128**, 606 (1962);

[3] W. Glenn, IEEE J. Quantum Electron. **QE-5**, 6 (1969).

[4] J. T. Manassah and O. R. Cockings, Opt. Lett. **12**, 12 (1987).

[5] S. L. Shapiro, Appl. Phys. Lett. **13**, 19 (1968).

[6] L. D. Noordam et al., Opt. Lett. **15**, 24 (1990).

[7] N.C. Khotari and X. Charlotti, J. Opt. Soc. Am. B **5**, 756 (1988).

[8] V. Roppo et al., Phys. Rev. A **76**, 033829 (2007); V. Roppo et al., Metamaterials 2, 135 (2008).

[9] M. Centini et al., Phys. Rev. Lett. **101**, 113905 (2008); Fazio et al., Opt. Express 17, 3141 (2009).

[10] V. Roppo et al, Phys. Rev. A **80**, 043834 (2009).

[11] T.W. Ebessen *et al.*, “Extraordinary optical transmission through subwavelength hole arrays”, Nature **391**, 667-669 (1998).

[12] M. A. Vincenti *et al.*, "Enhanced transmission and second harmonic generation from subwavelength slits on metal substrates", *Proc. SPIE* **6987,** 69870O (2008).

[13] E.D. Palik, *Handbook of Optical Constants of Solids* (Academic Press, London-New York, 1985).

[14] R. W. Boyd, *Nonlinear Optics*, (Academic Press, London-New York, 1992).